

972,620



## PATENT SPECIFICATION

DRAWINGS ATTACHED

972,620

Date of Application and filing Complete Specification: Nov. 16, 1962.

No. 43407/62.

Application made in United States of America (No. 153,534) on Nov. 20, 1961.

Complete Specification Published: Oct. 14, 1964.

© Crown Copyright 1964.

Index at acceptance:—B3 A10; B3 V4A1; O7 B(3C, A1G2)

International Classification:—B 23 p (C 23 b)

## COMPLETE SPECIFICATION

## Improvements in or relating to Electrode Tools for Electrical Machining

We, GENERAL ELECTRIC COMPANY, a corporation organised and existing under the laws of the State of New York, United States of America, of 1 River Road, Schenectady 5, New York, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed to be particularly described in and by the following statement:—

This invention relates to a tool for metal removal useful as a cathode in electrical machining and method of its manufacture.

One form of the art of removing metal from the workpiece to form an article includes the use of electrical energy. In such a process, sometimes referred to as "electrical machining", electrical energy passes between the workpiece as an anode and a tool as a cathode to dislodge selected portions of the workpiece. One type of electrical machining, sometimes called "electro-discharge machining" employs a discharging spark through a dielectric fluid to remove material. Another form of electrical machining, sometimes referred to as "electrochemical machining", does not discharge a spark between the workpiece-anode and tool-cathode but employs an electrolyte in a process which is the reverse of electro-deposition. Such a process is described in British patent 335,003—Gusseff.

In order to produce a contoured surface by electrical machining, it is necessary that a tool or die be made which can act as a cathode. Such a cathode generally cannot be in the form of the mirror image of the surface of the article which it is intended to generate. This is particularly true in electrochemical machining because current flows in varying amounts toward the workpiece from portions of a cathode immersed in an electrolyte with the workpiece. In this way, varying amounts of workpiece material are removed along the sides of

the workpiece which are not in the direct path traversed by the cathode. Thus a particular cathode will generate in a tool a cavity distorted in dimensions from that of the cathode according to such electrical machining variables as (1) operating gap between cathode and anode at the operating fluid pressures, (2) straying of current through the fluid medium between the cathode and the anode to result in variation of material removal according to relative positions of cathode and anode, (3) fluid flow rate, (4) feed rate, (5) current density, (6) fluid properties, and the like. Conversely, if a particular shape is desired in an article, the cathode-tool from which it is made must have such variables factored or integrated into its design.

Historically, the manufacture of cathodes of this type which could not be cast in final form has been a complicated and tedious job involving much trial and error. The production of the initial three dimensional surface has always been a time consuming operation sometimes involving forging, stamping, mechanical machining, grinding and the like. In addition to the larger amount of hand labor required, there are tedious checking procedures to determine if the die is accurate.

The object of this invention is to provide a relatively inexpensive method of making a complex shaped metal removal tool suitable for use as a cathode in electrical machining by automatically factoring and integrating into the method the variables which govern the electrical machining of a surface which the tool is intended to make.

In accordance with the invention there is provided a method of making a tool suitable for use as a cathode in electrical machining which comprises the steps of positioning an electrically conductive model of a surface to be reproduced in spaced relationship with and facing an electrically conductive tool

BEST AVAILABLE COPY

workpiece; applying electrical potential between the model surface and the tool workpiece so that the model surface is a cathode and the tool workpiece is an anode, the model surface and the tool workpiece being in electrical machining relationship with each other through a fluid medium; and then reducing the spacing between the model surface and the tool workpiece to allow electrical machining to progress until there is produced in the tool workpiece a profile similar but complementary to that of the model surface and of such dimensions that, when the tool workpiece is used as a cathode in a subsequent electrical machining operation, the machined article, as anode, will have the same dimensions as those of the model surface.

The electrically conductive model of a surface may be positioned in spaced relationship with and facing a plurality of electrically conductive tool workpiece segments.

In the accompanying drawings:

Figs. 1, 2 and 3 are schematic representations of the method of this invention;

Fig. 4 is an isometric view of a tool made according to the present invention and the model from which it was made.

Figs. 5, 6 and 7 are cross-sectional, partially diagrammatic views of the tool in the process of copying the model from which the tool of Fig. 4 was made;

Fig. 8 is an isometric partially sectional view of an article which can be used as a model or produced according to this invention;

Figs. 9, 10 and 11 are fragmentary, diagrammatic cross-sectional views of the model in the process of making tool segments for use in subsequent copying of the article or a model of the article of Fig. 8; and

Figs. 12, 13 and 14 are fragmentary, diagrammatic sectional views of a segment of the tool made in Figs. 9-11 in the process of reproducing a portion of the article of Fig. 8.

As was stated before, accurate use of electro-chemical or electro-discharge action as a metal working tool to manufacture an article requires that the cathode be shaped to produce the required workpiece. Generally the tool cavity will be distorted in shape from that of the workpiece desired, the distortion being governed according to the electrical machining variables significant in each particular case. In some instances where simple shapes are to be reproduced, the major and controlling variable will be the gap maintained between the cathode-tool and the workpiece. An example of such distortion is shown in the drawing. For purposes of simplicity of viewing, a cathode 20 is represented in Fig. 4 by a rectangular block. If such a block is a cathode, uninsulated on its sides, and is moved in an electrochemical machining process toward a workpiece 23 as shown in Figs. 1, 2 and 3, the resulting cavity 24 in Fig. 3

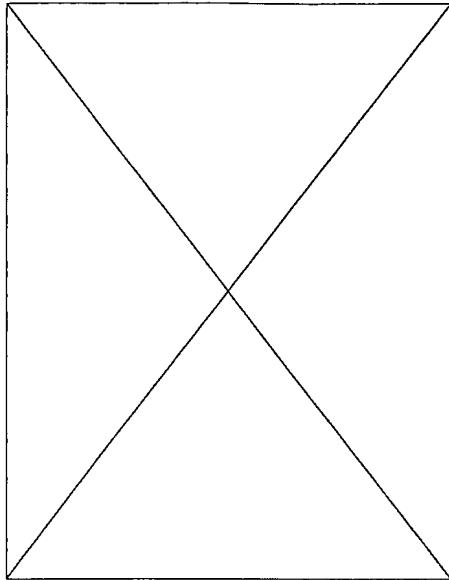
will have a distorted form. It is to be noted that walls 21 of cavity 24 taper away from the side wall surfaces 22 of cathode 20, as shown more clearly in Fig. 3. The distortion or tapering is caused by the continuation of electrochemical erosion as represented by electrical path 29 between the side walls 22 and the workpiece 23 even though the principle or concentrated electrical machining force is concentrated between the workpiece 23 and bottom surface 25 of the cathode 20. Although there is a decreasing amount of activity between workpiece 23 and cathode 20 near the surface of the electrolyte which fills cavity 24 in Fig. 3, nevertheless there is a definite relationship between the distorted shape of the cavity and the electrical machining variables mentioned before. It has been found that such variables which produce the distorted shape of the cavity in workpiece 23 also integrate within that distorted shape a pattern or map which can be used as a tool under the same processing conditions to reproduce an article.

Figs. 5, 6 and 7 show in partially diagrammatic form the use of tool 23 to reproduce an article 20a in Fig. 7 which is of the same dimensions and shape of Article 20 of Figs. 1-4. In Fig. 5, tool 23 which was the workpiece (anode) in the operations of Figs. 1-3 now becomes the tool or cathode. It is moved in the electrical machining process such as through an electrolyte in electro-chemical machining toward workpiece 26 under the exact processing conditions in which tool 23 was made.

Although the article and tool of Fig. 4 are of simple shape, this invention has been found very useful for the manufacture of complex shaped surfaces of article such as blading for turbomachinery. A tool manufactured according to this invention, although it is distorted in shape from the surface which it is intended to reproduce, nevertheless has integrated into its shape the complex contoured characteristics of the model surface.

Because of the complex relationships between portions of the airfoil of such blading and its base, it has been found to be more preferable to form portions of the article independently through use of more than a single tool. For example, a tool segment can be made to reproduce the surface representing one-half of the blade and its base portion whereas another tool segment can be used to form the second half of the blading and its accompanying base portion. Such tool segments can be used in separate operations to form portions of the blade or they can be used together to make a complete tool to form the entire blade at one time.

Tools manufactured according to the method of this invention can be a single tool indexed according to well known indexing means to reproduce multiple surfaces on an



stances, the tool can be  
ity of tool segments which  
amed, scheduled and co-  
duce more than a single  
le at the same time.

this invention is shown in  
s desirable to manufacture  
generally at 27 comprising  
egral part of a shaft 30, an  
model of the article can  
the manufacture of a tool  
vention. If the model of  
shown generally at 27 is  
l which will not conduct  
or its operation as an elec-  
tive surface can be applied  
del can be made according  
ods. For example, a model  
lightly undersize to accom-  
an be coated by the vapor  
ing with a metallic mater-  
spraying with a solution or

25 slurry including compounds reducible to a  
metal, etc. Such a reducible solution which has  
been successful consists of an aqueous solution  
of 6—8 ounces per gallon of  $\text{AgNO}_3$  to which  
 $\text{NH}_4(\text{OH})$  has been added until the precipi-  
tate which forms at the initial addition  
30  $\text{NH}_4(\text{OH})$  redissolves. This solution can then  
be applied to the surface of model 27 along  
with a reducing agent, such as formaldehyde,  
to deposit an electrically conductive film of  
silver on the surface of the model.

35 After a conductive model is made, elec-  
trical leads can then be attached to the surface  
of model 27 to afford the application of elec-  
trical energy. As shown in Fig. 9, conductive  
model 28 is a cathode and tool workpiece seg-  
ments 32, 32a, 32b, etc. are anodes in an  
40 electro-chemical machining operation. In this  
phase of the method, programing means 33  
controls, schedules and coordinates the rela-  
tive movement of the workpiece segments and  
the model as represented by arrows 34, 34a,  
45 34b and the like. Programing means 33 in

In the method steps of Figs. 12, 13 and 14,  
the tool segments 32, 32a and the like become  
the cathodes to be used in the reproduction of  
articles in the shape of article 27 from an  
anode-workpiece 40. This is accomplished by  
programing, for example in electrochemical  
70 processing, the same conditions under which  
the tool segments 32, 32a and the like were  
made. It is to be noted that in Figs. 12, 13  
and 14 all of the tool segments 32, 32a, etc.  
75 are the cathodes and article workpiece 40 is  
the anode.

Through the practice of the method and  
through the use of the tool of this invention,  
complicated three dimensional surfaces or  
complex shaped articles can be made from  
80 relatively inexpensively manufactured tools in  
electrical machining operations, for example,  
electrochemical machining. The models from  
which the tooling is made can be an article  
itself or can be a model made from a variety  
of materials, such as plastics, ceramics, metals,  
wood, and the like. Through the use of auto-  
matic programing means such as of the elec-  
trical, electronic, hydraulic, mechanical and the  
90 like, well known in the field of automation  
and electronics, the tedious, time consuming  
efforts are substantially eliminated in re-  
production of a tool distorted in the proper  
way to reproduce an article. The automatic  
95 devices and inherent functions of this inven-  
tion take all of these variables into considera-  
tion. Furthermore, the conditions under which  
the tool was made can be recorded for sub-  
sequent use to activate the programing means  
100 through such means as recording tapes, cards,  
or the like.

#### WHAT WE CLAIM IS:—

1. Method of making a tool suitable for use  
as a cathode in electrical machining which  
105 comprises the steps of positioning an elec-  
trically conductive model of a surface to be  
reproduced in spaced relationship with and  
facing an electrically conducting tool work-

facing a plurality of electrically conductive tool workpiece segments.

3. Method for making an article using the tool workpiece or workpieces made according to claim 1 or claim 2, which comprises positioning the tool workpiece or workpieces in spaced relationship with and facing an electrically conductive article workpiece; applying electrical potential between the tool workpiece or workpieces and the article workpiece so that the tool workpiece or workpieces is a cathode and the article workpiece is an anode, the tool workpiece or workpieces and the article workpiece being in electrical machining relationship with each other through a fluid medium, and reducing the spacing between the tool workpiece or workpieces and the article workpiece to allow electrical machining to progress, the electrical machining variables being programmed between anode and

cathode to reproduce the same conditions in the production of the article workpiece as existed in the production of the tool workpiece.

4. Tool made in accordance with Claim 1 or 2. 25

5. A method of producing a forming tool for electrochemical machining substantially as described with reference to Figs. 1, 2 and 3 or Figs. 9, 10 and 11 of the accompanying drawings. 30

6. A method of forming a workpiece with one or more forming tools according to claim 5 substantially as described with reference to Figs. 12, 13 and 14 of the accompanying drawings. 35

WM. BROOKES & SON,  
Chartered Patent Agents,  
Premier House, 12-13 Hatton Garden,  
London, E.C.1.

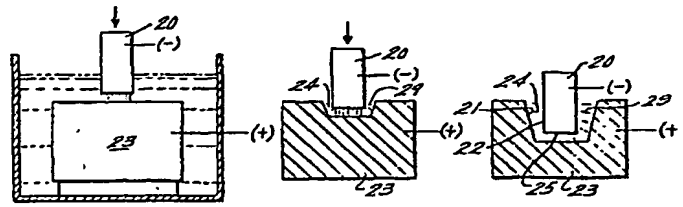


Fig 1

Fig 2

Fig 3

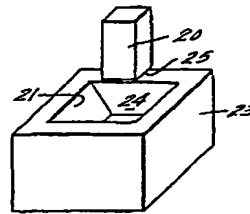


Fig 4

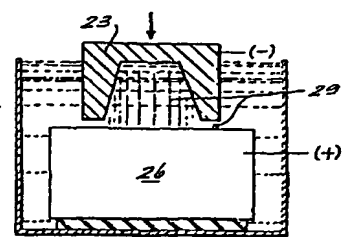


Fig 5

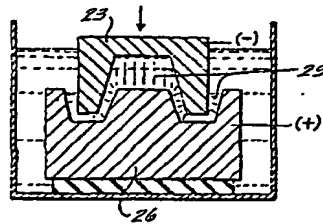


Fig 6

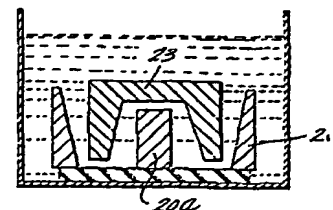
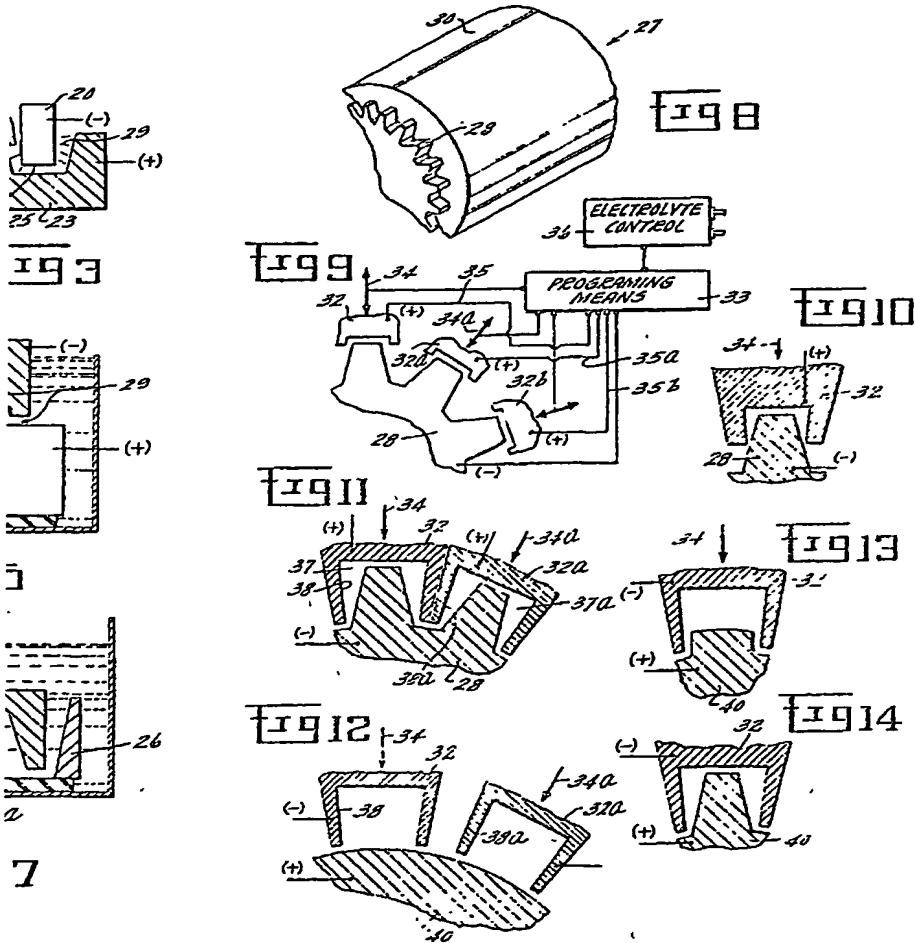
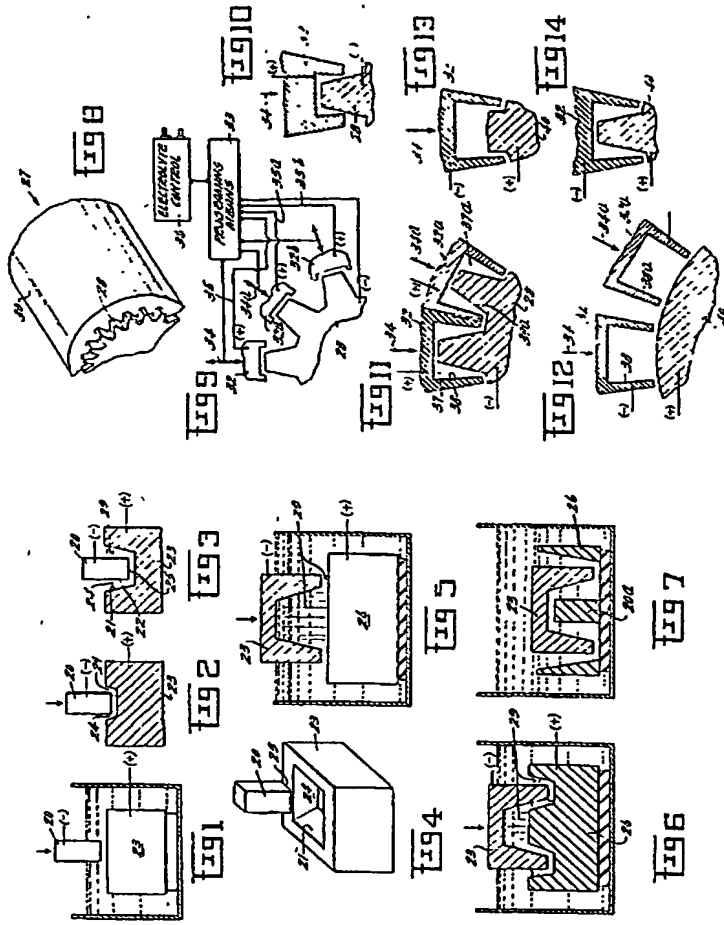


Fig 7





**This Page is Inserted by IFW Indexing and Scanning Operations and is not part of the Official Record.**

## **BEST AVAILABLE IMAGES**

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

- ☐ **BLACK BORDERS**
- ☐ **IMAGE CUT OFF AT TOP, BOTTOM OR SIDES**
- ☐ **FADED TEXT OR DRAWING**
- ☐ **BLURRED OR ILLEGIBLE TEXT OR DRAWING**
- ☐ **SKEWED/SLANTED IMAGES**
- ☐ **COLOR OR BLACK AND WHITE PHOTOGRAPHS**
- ☐ **GRAY SCALE DOCUMENTS**
- ☒ **LINES OR MARKS ON ORIGINAL DOCUMENT**
- ☐ **REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY**
- ☐ **OTHER:** \_\_\_\_\_

**IMAGES ARE BEST AVAILABLE COPY.**

**As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.**